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FOOD QUALITY AND ENERGY USAGE IN FOODSERVICE SYSTEMS: CONVECTIVE THERMAL PROCESSING OF TURKEY ROLLS

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This study evaluated sensory and nutritional qualities, microbiological and chemical safety of turkey rolls and energy use during convective thermal processing. Turkey rolls were heat processed in home or institutional convection ovens to an internal temperature of 77 to 80°C in the geometric center of the roll. Treatment combinations included three heat-processing temperatures (105, 135, and 165°C) and two holding treatments (not chilled and chilled for 24 hr) and three hot-holding times (0, 60 and 120 min).

Sensory studies of white turkey meat roasted at 165°C and reheated showed that juiciness decreased significantly ($p<0.05$), compared to roasting at 105 or 135°C without reheating. Juiciness was also decreased significantly ($p<0.05$) as hot-holding progressed (0 to 120 min).

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19. ABSTRACT (Continued)

Thiamin content was decreased by heat processing and, to a lesser extent, by hot-holding the turkey. Chilling meat prior to slicing and then reheating and holding did not have a detrimental effect on thiamin content.

Roasting to 77°C reduced the total aerobic counts from as high as 560,000 to less than 300 per g and destroyed all coliforms. However, the microbial load of the uncooked product was great enough to indicate the need for care in processing for public health protection.

Polychlorinated biphenyl (PCB) analyses of commercial raw turkey white meat obtained from turkey rolls showed less than 5 ppb of this environmental contaminant.

When two turkey rolls were heat processed at 105, 135 or 165°C, energy consumption, on both a load and a product weight basis, was significantly ($p<0.05$) different between 105 and 165°C. At 135°C, energy usage on a watt hours/kilogram (Wh/kg) basis was significantly ($p<0.05$) greater for two than for either four or six rolls. Implications of these data are that convection ovens should be operated to maximize product yield and minimize energy consumption.

18. SUBJECT TERMS (Continued)

MICROBIAL SAFETY
CHEMICAL SAFETY
TURKEY ROLLS

SUMMARY

One of the three objectives of the North Central Regional Research Project" Food Quality and Energy Usage in Foodservice System: Microwave and Convective Thermal Processing" is to establish parameters for conserving nutritional and sensory qualities and for maintaining microbial and chemical safety of menu items. Numerous criteria were established for product selection. These included: substantial source of protein, uniform product, requires thermal processing, large volume as used in the foodservice industry, reasonable cost, reliable suppliers, widely accepted and is of importance now and expected to be of importance into the 21st century. Turkey rolls were chosen as the first product to be used in the investigation under contract with the Department of the Army, U.S. Army Natick Research, Development and Engineering Center, Natick, MA.

The results of using forced-air convection ovens operating at 105, 135, and 165°C to roast turkey rolls to 77°C-80°C showed that sensory qualities and nutrient retention varied slightly. Holding sliced turkey from 0 to 120 minutes also resulted in slightly lower average thiamin retention; however, the small differences in the data negate the significance of the statistical findings.

Roasting to an internal temperature of 77°C-82°C eliminated all coliforms, an indicator of public health significance. PCBs were not detected. Yield, roasting time, and energy usage were significantly affected by oven temperature. Energy usage was also affected by oven load. This information contributes to a second objective which is to determine energy expenditure for different thermal processing parameters.

The final objective is to develop a data base on food quality and energy expenditures for use in decision making models for effective foodservice management. Data from this research project provide a basis for foodservice administrators to balance oven availability, product need, product quality, and energy usage. Further development of the data base with information from other food products will increase the body of knowledge available about foodservice technology.

Results of this study will be useful to managers in all segments of the foodservice industry. Additional studies need to be done, using data generated by this project based on actual time and temperature relationships, to develop models that can predict quality and energy usage of the food product. Collaborative studies of quality and safety characteristics as well as energy use under comparable time and temperature relationships should be continued. Other menu items (e.g. fish products) and other classes of foods (e.g. vegetables) need investigation.

PREFACE

This project was completed under contract (DAAK60-84-C-0089) with the Department of the Army, U.S. Army Natick Research, Development and Engineering Center, Natick, MA., supplier of the turkey rolls. The work was directed by the North Central (NC-120) Regional Research Committee of the United States Department of Agriculture. The research was administered through the Agricultural Experiment Station system in nine states as follows:

State	Area of specialization	Project Leader
Illinois	Nutritional Quality	Dr. B.P. Klein Univ. of Illinois
Iowa	Energy Usage Sensory Evaluation Nutritional Quality	Dr. N. E. Brown Iowa State Univ.
Kansas	Sensory Quality Nutritional Quality	Dr. C.S. Setser Kansas State Univ.
Michigan	Chemical Safety	Dr. M.E. Zabik Michigan State Univ.
Minnesota	Microbiological Quality	Dr. E.A. Davis Univ. of Minnesota
Missouri	Energy Usage	Dr. N.F. Unklesbay Univ. of Missouri
Nebraska	Fundamental Microbiology	Dr. R.B. Maxcy Univ. of Nebraska
Ohio	Sensory Quality	Dr. M.L. Cremer Ohio State Univ.
Wisconsin	Energy Usage Microbiological Quality Nutritional Quality	Dr. M. E. Matthews Univ. of Wisconsin- Madison

The researchers wish to acknowledge the cooperation, interaction and technical expertise of Dr. D. B. Rowley, Chief of the Biological Sciences Division, Science and Advanced Technology Directorate, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA.

Special appreciation is extended to the following members of the NC-120 Regional Research Committee for their leadership role in the research and the writing of sections of this report.

Section	Researcher
Food Preparation Procedures and Measurements for Turkey Rolls	Dr. N.E. Brown Iowa State University and Dr. C.S. Setser Kansas State University
Sensory Quality	Dr. C.S. Setser Kansas State University
Nutritional Quality	Dr. B.P. Klein University of Illinois
Microbiological Safety	Dr. R.B. Maxcy University of Nebraska
Chemical Safety	Dr. M.E. Zabik Michigan State University
Energy Usage	Dr. N.F. Unklesbay University of Missouri-Columbia

Other contributors to this project were Dr. J. Love, who supervised the nutritional analysis of turkey rolls at Iowa State University, Dr. J.A. Milner from the Illinois Agriculture Experiment Station who is the Administrative Advisor to NC-120, and Dr. R. Garner from the U.S. Department of Agriculture who is the USDA Advisor to NC-120. We also acknowledge G.N. Bookwalter, from the USDA Northern Regional Research Center in Peoria, Illinois who is a liaison representative to NC-120, for his helpful comments on the final draft of this manuscript.

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FOOD QUALITY AND ENERGY USAGE IN FOODSERVICE SYSTEMS: CONVECTIVE THERMAL PROCESSING OF TURKEY ROLLS

INTRODUCTION

Forecasts for foodservice sales during 1986 show differences of opinion among estimates by Restaurants and Institutions Magazine, the National Restaurant Association, and Technomic Consultants. These differences are partially related to methods of data accumulation and to assumptions about inflation (Table 1). However, all three agree on a conservative rate of real growth for the military segment (1).

The foodservice industry consists of individual market segments that have specialized requirements for food, equipment and supplies and use unique methods of purchasing, storing, preparing and serving meals and snacks to meet the needs of customers. Therefore, expansion or shifts in trends within market segments will probably have implications for the numerous businesses (food, equipment, supplies, and services) that sell goods and services to the foodservice industry (2).

Changes in consumer attitudes and lifestyles will continue to affect many of the foodservice industry segments in the future. Consumers are likely to continue to be interested in health and nutrition with a concomitant taste for healthful menu items such as poultry, salads, and vegetables (3). When making decisions about menu items, administrators in military, commercial, and institutional foodservices consider food quality and cost. Quality food is selected, prepared, and served so that the food is microbiologically and chemically safe, retains or enhances sensory properties, conserves nutrients, and is sought by consumers. Food quality is probably affected more by thermal processing than any other step in food preparation. The primary focus of this

TABLE 1. Forecasts for Foodservice Sales During 1986 by Market Segment.[a]

Market Segments	Restaurants & Institutions[b] (4.6% inflation)		National Restaurant Assoc.[c] (3.9% inflation)		Technomic Consultants[d] (5.1% inflation)	
	1986 sales in millions	Real growth	1986 sales in millions	Real growth	1986 sales in millions	Real growth
Full service	$ 57,680	+0.9%	$ 67,300	+2.9%	$ 55,752	-0.9%
Fast food	48,250	+2.9	52,699	+4.7	56,099	+4.7
Hotels and motels	6,455	+0.5	11,713	+3.7	6,640	-0.5
Recreation	3,961	-0.2	5,633	+3.7	5,885	+2.0
Convenience	3,728	+5.6	--	--	1,629	+7.0
Retail	2,204	-0.9	6,076	+7.1	4,158	+2.4
Bars and taverns	--	--	8,040	-2.4	1,141	-3.0
TOTAL COMMERCIAL	$122,278	+2.0%	$151,461	+2.8%	$131,304	+1.9%
Schools	$ 13,043	+2.0%	$ 3,670	0.0%	$ 12,739	-0.5%
Hospitals	7,721	-3.0	8,116	-3.1	9,305	-2.9
Nursing homes	10,489	+2.7	5,906	+1.8	13,336	+2.0
Business & industry	3,717	+1.7	3,663	+1.4	3,786	+2.0
Colleges & universities	6,164	-0.4	5,036	+0.4	5,569	+0.5
Military	4,517	+1.0	932	+2.8	5,276	+0.5
Vending	--	--	4,175	+3.3	12,425	+2.5
Transportation	2,603	+2.4	1,832	+3.9	2,795	+2.0
TOTAL INSTITUTIONAL	$ 48,254	-1.4%	$ 33,330	+0.6%	$ 57,202	+0.7%
All other foodservice	$ 1,738	+0.5%	$ 1,033	+2.3%	$ 3,412	+1.4%
TOTAL FOODSERVICE MARKET	$172,270	+1.4%	$185,850	+2.8%	$203,889	+1.5%

a Adapted from Restaurants & Institutions, 1986(1).

b No alcoholic beverage sales are included. Commercial cafeterias are included in full-service. Convenience includes grocery. Vending sales are included in the market segment where they occur. In all institutional (captive) segments, figures are calculated as commercial-sales equivalents, based on food purchases. Food contractor sales are included in the segment where they occur. Separate drinking place food sales are included in full service. "Other" includes primarily social clubs, prisons and recreation camps.

c NRA includes alcoholic beverage sales in all figures. In the institutional (captive) segments, actual dollars spent are reported. Commercial equivalents are calculated for nursing homes. Sales for food contractors are added here to the segment where the sale occurs. Vending figures include only food and beverages. Commercial cafeterias and social caterers are included in full service. Mobile cafeterias and community centers are included in "other" foodservice. Military figures are for the continental United States only. Convenience store food sales are part of retail.

d Transportation figures are from airlines only. Alcoholic beverage sales are not included in any market segment. In all institutional (captive) segments, figures are calculated as equivalent commerical sales, based on food purchases. Vending sales include all food and beverages. Separate drinking place sales (food only) are included in full service. "Other" includes prisons, convents, clubs, railroads, ships and miscellaneous segments. Total institutional includes other captive. Grocery stores are included in retail.

two-year component of a five-year project was convective thermal processing, because convection ovens are widely used throughout the foodservice industry.

There were three primary objectives for this project (1984-1986):

1. Establish parameters for conserving nutritional and sensory qualities of a menu item, while maintaining microbial and chemical safety.
2. Determine energy expenditures for different thermal processing parameters used in preparing a selected menu item in forced-air convection ovens.
3. Develop a data base on food quality and energy expenditures for a selected menu item for use in decision making models for effective foodservice management.

Experimentation was limited to convective thermal processing for foodservice systems. A menu item was selected that met the following criteria, established by the North Central-120 Regional Research Committee:

1. Product contains one or more critical nutrients; at least one product shall have substantial protein content.
2. Product is fairly uniform in product composition.
3. Product is appropriate to convective thermal processing.
4. Product is used in large volume by the foodservice industry.
5. Product is of reasonable cost.
6. Product has reliable supplier.
7. Product is widely accepted within the general population.
8. Product is of importance now and is expected to be of importance into the 21st century.

The menu item selected as meeting these criteria was turkey rolls (frozen). Consumption of turkey meat in both the retail and commercial markets has been increasing over the last 25 years (4). The turkey rolls, formulated according to commonly accepted specifications and available from a dependable source, were provided by the U.S. Army Natick Research and Development Center through contract (DAAK60-84-C-0089). Turkey rolls were from a single lot; thus individual rolls constituted a random sample.

The research work was completed in three phases to maximize the effectiveness of joint efforts among the universities and to take advantage of the combined expertise in food quality and energy usage methods for foodservice research. The type of research, quality factors studied, and research sites with major responsibility for procedures are shown in Table 2.

TABLE 2. Quality Factors Studied and States with Major Responsibility for Procedures

Type of research	Sensory quality	Nutritional quality	Microbiological safety	Chemical safety	Energy use
Standardization of methods	Kansas	Illinois	Nebraska	Michigan	Missouri
Validation of methods and findings	Illinois Iowa	Kansas Wisconsin	Minnesota	Michigan	Iowa Wisconsin
Application to foodservice	Iowa Ohio	Iowa Wisconsin	Nebraska Wisconsin	Michigan	Iowa Missouri Wisconsin

The product to be used, variables to be studied, and procedures for the study were predefined, validated, and followed by the researchers contributing to the project.

METHODS AND MATERIALS

EXPERIMENTAL DESIGN

Most phases of this experiment involved with six treatment combinations. The treatment combinations included three cooking temperatures (105, 135, and 165°C) and two holding treatments (not chilled and chilled for 24 hr). Turkey rolls from each treatment combination were subjected to three hot-holding times (0, 60, and 120 min). Zero time for hot-holding was reached when half of the thermocouples indicated that the internal temperature of turkey slices had reached 66 to 67°C or above. Thereafter, slices were held for 60 or 120 min. Turkey rolls were cooked at the selected temperature, then sliced and held for the three hot-holding times or chilled for 24 hr before slicing, reheating, and holding. The combinations of cooking time and holding treatment were selected randomly and specified for each day of the study.

DESCRIPTION OF PRODUCT

The frozen, raw, boneless, ready-to-cook turkey rolls were formulated in accordance with USDA specifications which were: breast meat (minimum 47.0% of total), thigh meat (maximum 34.0%), skin (maximum 12.5%), water (5.0%), iodized salt (1.0%), and sodium phosphates (0.5%). Breast meat could replace thigh meat, and either breast meat or thigh meat could replace skin. The maximum percentage of thigh meat could be exceeded if thigh meat replaced skin and the minimum percentage of breast meat was obtained. A minimum of 75% of the outer surface was to be covered by skin. The finished product requirements for the turkey rolls allowed for variations in length (23 to 43 cm), diameter (10 to 18 cm), and weight (3.6 kg to 5.4 kg). Norbest Incorporated, Salt Lake City, Utah was the supplier of the turkey rolls to the U.S. Army Natick Research and Development Center. These rolls were netted and placed in sealed moisture-proof casings, frozen and shipped to arrive at each research site between October 1984 and January 1985.

PREPARATION FOR THERMAL PROCESSING

Turkey rolls were held in frozen storage, at approximately -20°C. Prior to roasting, rolls were thawed at 4°C for 48 to 72 hr to an internal temperature of 0 to 6°C in the geometric center of the roll. The moistureproof bag was removed from the thawed turkey roll just prior to cooking, while the net was left in place.

Turkey rolls used for sensory and microbiological studies were roasted within 4 to 8 months after receiving the products. Nutritional, chemical, and energy studies were completed within approximately 9 months.

Two sizes of forced convection ovens (household and institutional) were used to evaluate extremes in oven sizes as might be used in military foodservice. The household oven was a Farberware Convection turbo-oven (Model 460/5). Turkey rolls were cooked, uncovered, to an internal temperature of 80°C in the geometric center of the roll (Illinois and Kansas). The electric institutional convection ovens used included: Zephaire Model EF-111, the G.S. Blodgett Company Inc. and Lang Model ECCO-6, the Lang Manufacturing Company. Turkey rolls were also placed in the center of the oven, uncovered (Missouri and Wisconsin) or covered with aluminum foil (Iowa and Ohio) and cooked to an internal temperature of 77°C in the geometric center of the roll.

Time-temperature data were collected at the geometric center of the turkey roll by using recording potentiometers. Oven roasting temperature and internal meat temperature were recorded every 4 to 5 min throughout roasting and 15 to 30 min after roasting. Total cooking losses, drip and evaporative losses were based on cooked weights taken 15 min after the turkey rolls were removed from the oven. After standing for 15 min, the turkey roasts were either placed in a refrigerator at 4°C to chill overnight (Illinois, Iowa, Kansas and Ohio) or sliced into 1-cm slices (Illinois, Iowa, Kansas, Ohio and Wisconsin) for hot-holding. Slices for the 0 holding time were evaluated within 30 min of removal of the turkey roasts from the ovens. Temperature of the holding equipment was monitored and adjusted to maintain the internal temperatures of the turkey slices at 66 to 67°C.

Only white meat was sampled for quality evaluations so slices with maximum amounts of white meat were selected for holding. Turkey meat was held at 66°C in the geometric center for either 60 or 120 min. Four slices (about 495 to 500 g per pan) were held in covered disposable half-sized steam table pans or turkey slices were stacked in pans (approximately 800-g per pan). Various types of hot-holding equipment were used, but all equipment was calibrated so that the temperature in the geometric center of the meat when reheated was 66°C.

Chilled meat was removed from the refrigerator after 24 hr, sliced as described previously, and reheated at 105°C to an internal temperature of 66°C for the 0 holding time. Samples were then treated in the same manner as the turkey meat that was not chilled. Statistical tests, as appropriate for each parameter being studied, were done according to commonly accepted procedures for analyses.

QUALITY MEASURES

Sensory Analyses

Sensory analyses of turkey meat were conducted at four Agricultural Experiment Stations: Illinois, Iowa, Kansas, and Ohio.

Panelists. Faculty, staff, and students at the various universities were trained during a two-week period (3 hr per week) to do the sensory analyses of the samples of turkey meat. Seven to twelve panel members were trained. From pools of twelve panelists, four to six panelists were selected randomly at Kansas and Illinois, respectively, and assigned to sampling periods for every treatment and time. The same panelists were used at each taste panel session at Iowa and Ohio.

Training consisted of introducing panelists to the score card and defining terminology used in this study. Panel members were given samples and trained to recognize characteristics of the extremes, or anchors, for each attribute to be evaluated. The score card used in this study is illustrated in Figure 1.

Preparation of samples. Two or four 1-cm-thick slices of turkey from each holding period were used for sensory analyses. A 1.3-cm-diameter corer was used to cut sample cores for each panelist to determine chew count. Approximately 2 to 3-cm-diameter samples were used for evaluating other sensory attributes of the turkey.

Holding and serving of samples. Turkey cores were placed in prewarmed 50 to 150-mL glass beakers covered with watch glasses. Each sample had its own holding beaker. These covered beakers were placed in a pan of hot water maintained at approximately 62°C on an electric warming tray set at 93°C.

Panelists served themselves at the designated hour of testing by selecting two cores from each beaker. Reference samples for aroma, representing partially roasted and extensively-roasted turkey to develop browned aromatics, were provided for the evaluators at Illinois and Kansas. These samples were held at room temperature in covered glass brandy snifters and retained their characteristic aromas.

Nutritional Analyses

Of the nutrients in poultry, thiamin is the most labile and, therefore, it was used as an indicator of nutritional quality because its destruction would

INTENSITY RATINGS: TURKEY ROASTS
LIGHT MUSCLE

Name________________________________
Date________________________________

Place a vertical line across the horizontal line at the point representing your perception of the characteristic's intensity. Re-testing is permitted.

AROMA

____
Partially cooked Roasted

JUICY MOUTHFEEL

____
Very dry Very juicy

TEXTURE

____
Fibrous, stringy Crumbly, mealy
Chew Count__________

FLAVOR: MEATY, COOKED TURKEY

____
None Intense

FLAVOR: OFF-NOTES

____
None Strong, stale

Thank you!

Figure 1. Score Card for Sensory Analysis of Turkey Roasts

be most likely to occur under adverse heat processing conditions. Although poultry is not an excellent source of thiamin, it provides about 40 to 60 mcg/100 g meat.

Thiamin content and retention were determined from turkey roasted in household size forced-air convection ovens (Illinois and Kansas) and institutional forced-air convection ovens (Iowa and Wisconsin). After roasting at 105, 135, and 165°C, chilling 24 hr at 4°C or not chilling and holding slices at approximately 66°C for 0, 60, or 120 min, approximately 50 g of the sliced white meat was removed for nutritional analysis. These samples were held frozen at -20°C until analyzed for thiamin using a modification of the thiochrome assay method (5). Thiamin was expressed as mcg/100 g on a wet-weight basis, using the AOAC method 24.003 (6).

Microbiological Analyses

Sampling and Evaluation of Raw Turkey Rolls. Following thawing, for each analysis an 11-g sample was removed aseptically by random selection from various areas of the surface of a turkey roll. To determine internal microbial contamination, a 2.54-cm core was taken aseptically from the midsection of a roll and an 11-g sample was removed from the middle of the cored portion. Each sample was then blended with 99 mL of phosphate buffer for subsequent decimal dilutions and platings in duplicate with plate count agar (PCA) and violet red bile agar (VRBA). Plate count agar was used to determine total aerobic plate count and VRBA was chosen to determine coliforms, indicators of microorganisms of public health significance. Plates were incubated at 32°C at Nebraska, 35°C at Wisconsin, and 37°C at Minnesota. The high temperature selected by Minnesota was chosen to correspond with standard medical procedures for evaluating pathogens in products. Incubation times for VRBA ranged from 18 to 24 hr with the shortest time associated with the highest temperature. Incubation time for PCA was 48 hr.

Sampling and Evaluation of Cooked Turkey Roasts. After cooking as described previously, turkey roasts were sliced into 1.0 to 1.2-cm pieces. Eleven-gram samples were taken aseptically from the approximate center of slices by Nebraska and Minnesota, while Wisconsin obtained samples from various areas on the surface of turkey roasts. Surface samples were also obtained by Wisconsin after hot-holding at 0, 60, and 120 min. Samples were blended and subsequent decimal dilutions were made. Platings were in duplicate on PCA and VRBA and incubated at 32 to 37°C for 48 and 24 hr, respectively. These procedures were in general accord with the methods outlined by Speck (7).

Chemical Analyses

PCB Analyses. Representative samples of turkey rolls in excess of 100 g were obtained from four states receiving turkey rolls from the common lot of turkey rolls supplied by the Department of the Army under this contract (Contract No. DAAK60-84-C-0089). In each of these states, the turkey rolls were sliced frozen using a band saw, and frozen samples were wrapped in foil and then placed in sealed polyethylene bags, packed in dry ice, and shipped by air to the Michigan Agricultural Experiment Station. All samples were received frozen. After receipt, the samples were thawed and the white meat separated. The white meat was pulverized in an Osterizer blender before duplicate 10-g samples were taken for polychlorinated biphenyl (PCB) analyses. PCBs were analyzed by hexaneacetone extractions, acetonitrile partitioning and Florisil-celite column cleanup according to the method of Yadrick et al. (8). An aliquot of the hexane was dried under vacuum at 70°C to estimate fat. Following the final concentration, PCBs were quantitated by capillary column gas chromatographic analysis using a Tracor 560 gas chromatograph (GLC) equipped with a ^{63}Ni electron capture detector and interfaced with a Spectra-Physics chromatograph integrator, model SP 4270. The capillary column for the GLC was a 0.25-mm x 30-m fused silica column with a 0.25-micron DB-1 stationary phase. Column pressure was 138 kPa. The initial oven temperature was 170°C and was programmed to rise at 4°C/min until it reached 270°C. Final holding time at 270°C was 10 min. The injector and detector temperatures were 250 and 300°C, respectively. Standards were prepared with Aroclor 1254 in nanograde hexane.

Quantitations were based on the area of the PCB peaks 3.22 to 24.30 of the Aroclor standard as illustrated in Figure 2. Standards were run at the beginning of each day and after every six samples. PCBs were expressed on an edible tissue, solid and fat basis. Recoveries of Aroclor 1254 from samples spiked with 50 ppb to 5 ppm 1254 were 98%±1%. Limit of detection was 5 ppb.

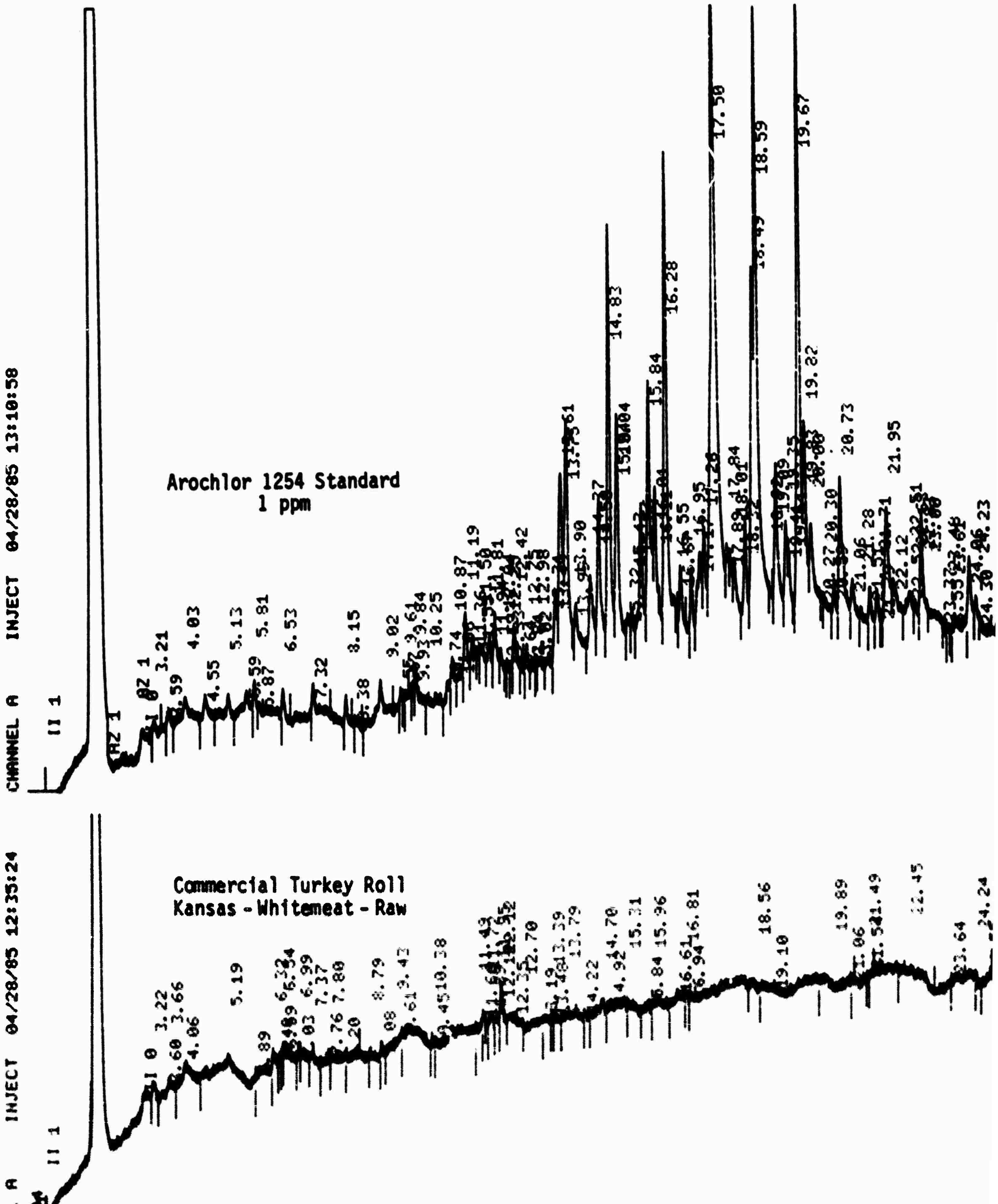

Figure 2. Comparison of Gas Liquid Chromatograph (GLC) Tracing of PCB Standard with that of Turkey Roll Samples.

Energy Usage

Electrical energy usage was monitored during three stages: convective thermal processing of the turkey roll (Iowa, Missouri, and Wisconsin), convective heating of chilled slices of turkey roll (Iowa), and convective hot-holding of the turkey slices (Iowa and Wisconsin). Procedures as described in the previous section were followed. A digital energy monitor (DuPont, Model EMT-KWD; DuPont Energy Management, Dallas, TX) was used to record energy consumed by the convection oven. Energy consumption in watt hours was recorded after the oven doors were closed and the oven was turned on until the internal product temperature of all the turkey rolls had reached 77°C. Energy usage was expressed as watthours/load (Wh/load) and watt-hours/kg (Wh/kg) of raw turkey rolls, for the thermal processing of the turkey rolls.

Scientists at Iowa and Missouri used an identical model of a forced-air convection oven and identical procedures. Their research design with this oven first involved heat processing with an oven load size of two turkey rolls at each of the three temperatures (105, 135, and 165°C). These data were pooled since conditions were identical in both Agricultural Experiment Stations. Additional data were collected with oven loads of 4 and 6 rolls at the oven temperature of 135°C. Again, because of similar conditions, data were pooled and statistically analyzed.

Scientists at Wisconsin used a different model of forced-air convection oven. The research approach used was to obtain energy data for each of the nine treatments, i.e., three different oven temperatures and three different oven load sizes. This coordinated approach presented information about energy consumption for each of these nine treatments.

Oven placement at all three Agricultural Experiment Stations was:

2 rolls -- Pans were placed adjacent to each other on one rack located in the center of the oven.

4 rolls -- Pans were placed adjacent to each other on two racks which were centered in the oven cavity.

6 rolls -- Pans were placed adjacent to each other on three racks which were centered in the oven cavity.

For the Lang convection ovens at Iowa and Missouri, the rack with two rolls was located 21.2 cm from the bottom of the oven. When four rolls were used, two rolls were placed 31.2 and 16 cm from the bottom of the oven, respectively. When six rolls were studied, two rolls were placed 36.1, 21.2, and 5.8 cm from the bottom, respectively. For the Blodgett convection oven at Wisconsin, the rack with two rolls was located 15.9 cm from the bottom of the oven; those for four rolls, 15.9 cm and 1.9 cm from the bottom of the oven; and those for six rolls, 29.8 cm, 15.9 cm, and 1.9 cm from the bottom.

For chilled slices at Iowa, the oven temperature was programmed for 105°C to heat the turkey slices to 60°C then the oven was reprogrammed for 66°C to maintain internal temperature of the slices at 66°C. When half of the thermocouples had reached 66°C, the 0-min holding time was reached. Turkey slices were held for 60 and 120 min thereafter. At Wisconsin, 4, 8, or 12 pans of sliced turkey meat (from oven loads of 2, 4, or 6 turkey rolls, respectively) were placed in a preheated (82°C) hot-holding cabinet (Hotpack, Model 1242-4, Philadelphia, PA) until internal temperature of the slices reached 67°C. Thereafter, slices were held for 60 or 120 min.

RESULTS AND DISCUSSION

TIME AND TEMPERATURE DATA

Heating times for turkey roasts prepared in home convection ovens at Kansas and Illinois are shown in Table 3. Differences in cooking times between Kansas and Illinois may be due to variation in initial meat temperature and size of the rolls. Cooking times were significantly ($P<0.05$) longer at the lower cooking temperatures. This trend was seen also in the foodservice studies at Wisconsin and Iowa. Representative heating curves for roasts cooked at the three oven temperatures in both home and institutional convection oven are shown in Figure 3.

TABLE 3. Heating Times for Turkey Roasts Prepared in Home Convection Ovens.

Cooking Temperature	Kansas	Illinois
(°C)	(← min/kg	→)
105	54.0	75.6
135	40.6	48.6
165	32.2	36.9

Time and temperature relationships were evaluated in terms of three oven loads and three oven temperatures at Wisconsin. The times needed to reach the predetermined oven temperature at different oven loads were significantly different ($P<0.01$) among the three oven loads of 2, 4, and 6 turkey rolls and three oven temperatures. As both the size of the oven load and the temperature of the oven increased, more time was needed to reach the predetermined oven temperature.

As shown in Figure 4, the cooking times for all turkey rolls to reach 77°C or above were significantly different ($P<0.01$) among the three oven

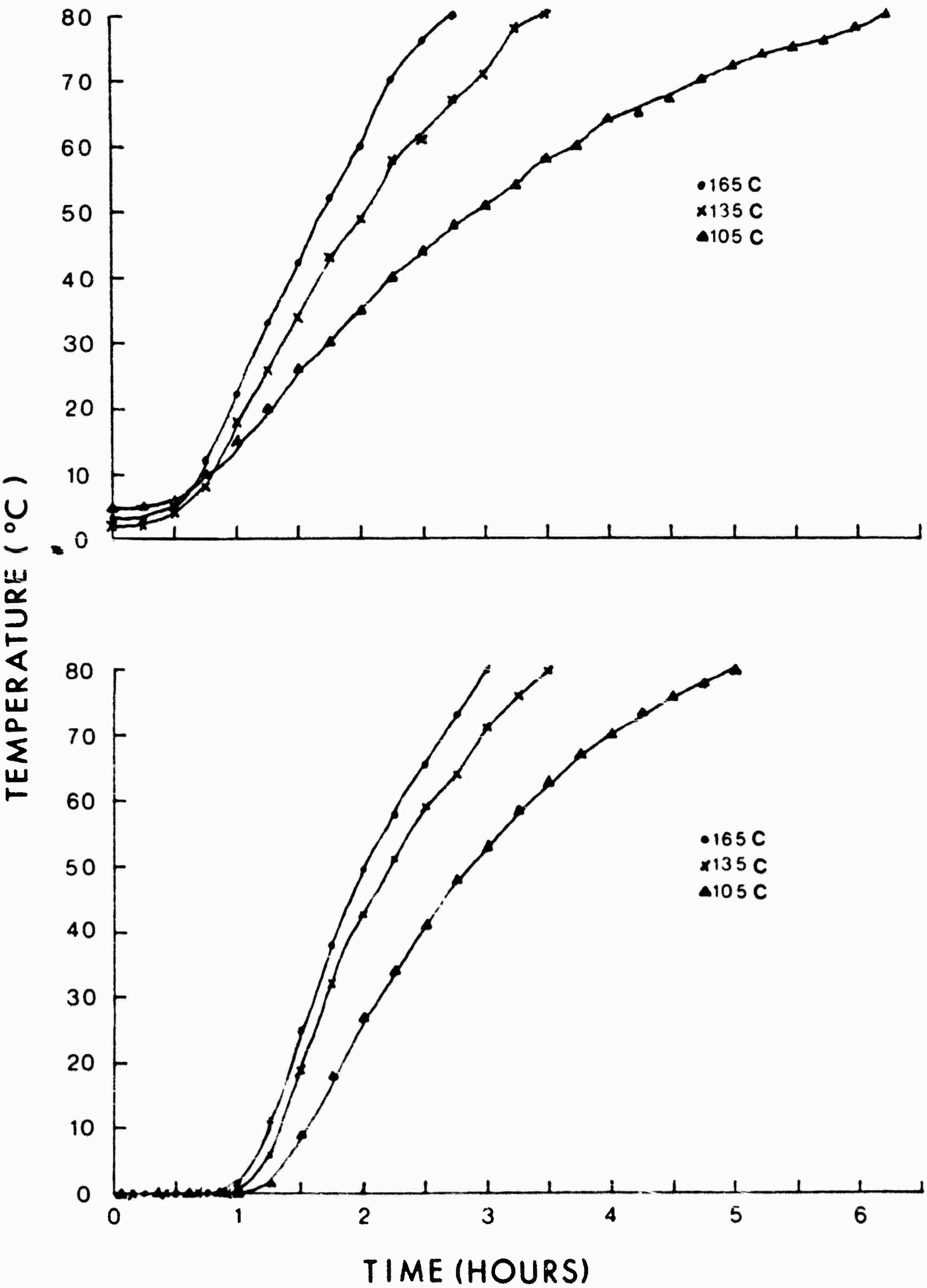

Figure 3. Representative Heating Curves for One Turkey Roast Cooked in a Home Convection Oven (above) and Two Turkey Roasts Cooked in an Institutional Convection Oven (below).

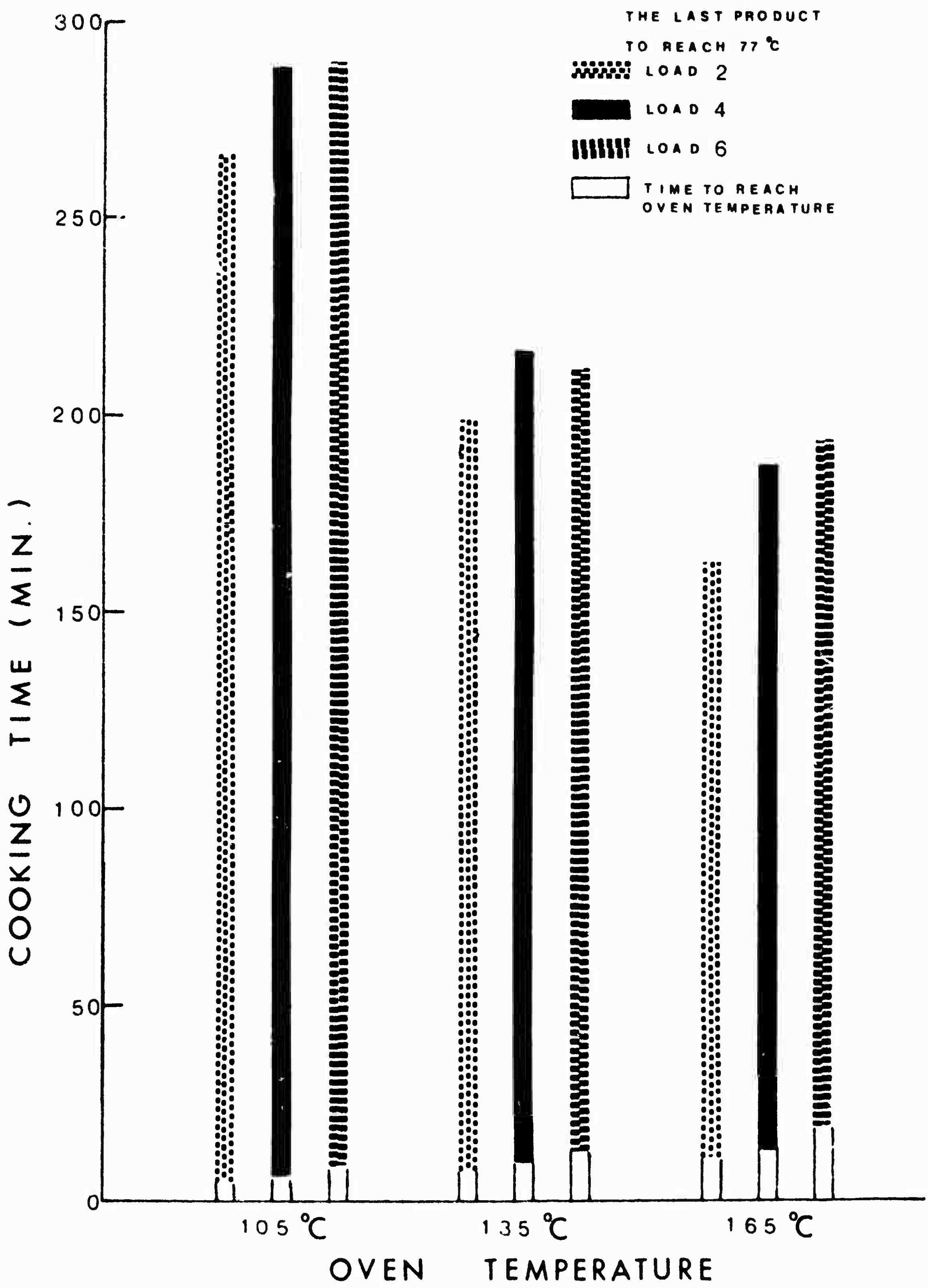

Figure 4. Time Needed to Reach Predetermined Oven Temperatures and Total Cooking Times for All Turkey Rolls to Reach 77°C or above in a Convection Oven When Using Three Oven Loads and Three Oven Temperatures.

temperature settings for all three oven loads. As the oven temperature increased, the cooking time decreased for all oven loads. The mean cooking times required by the three different oven loads were also significantly different ($P<0.01$). However, times used for oven loads of 4 and 6 rolls at all three oven temperature settings were quite similar.

Further statistical analysis was undertaken to assess more specifically the time differences between individual loads and individual temperatures. Results indicated that there was a significant ($P<0.01$) time difference between oven loads of 2 and 4 turkey rolls, but there was no significant difference between oven loads of 4 and 6 rolls at three temperatures. The time differences between 105 and 135°C were more than 60 min for all three loads. The differences between 135 and 165°C were 36 min, 29.5 min, and 18 min for oven loads of 2, 4, and 6 rolls, respectively. The differences between 105 and 135°C and also between 135 and 165°C were significantly different ($P<0.01$). When scheduling food production, it should be recognized that oven temperature and oven load affect cooking time and must be considered in relationship to the desired sensory, nutritional, and microbial quality of the finished product as well as energy consumed in the process.

PRODUCT YIELD

Product yield as affected by oven load was determined only for roasting at 135°C at Missouri and Iowa (Table 4). The highest product yield was found when 4 rolls were heat processed simultaneously versus 2 or 6 rolls. The total processing losses (both evaporative and drip) were significantly greater ($P<0.05$) when only 2 turkey rolls were in the oven cavity. Although relative humidity was not measured in these experiments, it probably increased as the number of turkey rolls increased, because they were heat processed in uncovered pans. This factor could account for differences in processing losses.

The mean weight values of turkey roll before and after heating and the percentage of yield after cooking (Wisconsin) are illustrated in Table 5. The product yield was significantly different ($P<0.01$) among three oven temperatures but not significantly different among three oven loads. The results for three oven loads agreed with those of Unklesbay et al. (9) They concluded that the oven load did not influence product yield for 24, 48, 72, or 96 sausage patties with convective heat processing. The Wisconsin study showed that lower oven temperatures for turkey roasts resulted in greater product yields (Table 5). However in a study of heat processing pizza crusts, Unklesbay et al. (10) noted that the greatest food product yield was obtained with the highest oven temperature and the shortest heat processing time. The reasons for the differences in product yield, according to cooking time and temperature may be due to (a) the size and weight of products, because a turkey roll is much larger, heavier, and higher in moisture than a pizza crust or sausage patty; (b) different oven temperature settings and heat processing times, because the time for cooking turkey rolls was at least tenfold greater than the time for heating pizza crust and sausage patties; and (c) different composition of food products; certain products are more likely to undergo case hardening, thereby influencing the rate of moisture diffusion.

TABLE 4. Heat Processing Parameters for Turkey Roasts.

Oven Temp	N[a]	Load Size No. Rolls	Initial Mass (g) Mean[b]	Initial Mass (g) S.E.[c]	Final Mass (g) Mean[b]	Final Mass (g) S.E.[c]	Total Processing Loss (%) Mean[b]	Total Processing Loss (%) S.E.[c]	Yield (%) Mean[b]	Yield (%) S.E.[c]
135	3	2	10002[Z]	23	7245[Z]	62	27.54[X]	0.44	72.45[Z]	0.44
135	3	4	19996[Y]	25	15430[Y]	83	22.83[Z]	0.35	77.16[X]	0.35
135	3	6	30514[X]	144	22986[X]	123	24.66[Y]	0.44	75.33[Y]	0.44

NOTES: Combined data from Iowa State and University of Missouri

[a]Refers to the number of replications.

[b]Means within a column followed by the same letter are not significantly different ($P<0.05$).

[c]Standard error.

TABLE 5. Mean Weights of Turkey Roasts Before and After Heating and the Percentage of Yield in a Convection Oven at Three Oven Loads and Three Oven Temperatures at Wisconsin.

Loads		Temperatures[a] 105°C	135°C	165°C
2[b]	Before (kg)	4.98±0.07[e]	4.95±0.15	4.90±0.10
	After (kg)	3.89±0.10	3.66±0.19	3.54±0.15
	(% Yield)	(78.04±3.28)	(73.96±1.53)	(72.15±1.72)
4[c]	Before (kg)	5.07±0.19	4.90±0.20	4.94±0.16
	After (kg)	3.94±0.30	3.55±0.21	3.36±0.16
	(% Yield)	(77.60±3.85)	(72.46±2.32)	(68.06±2.89)
6[d]	Before (kg)	4.94±0.06	4.96±0.13	4.92±0.09
	After (kg)	3.86±0.12	3.55±0.16	3.44±0.14
	(% Yield)	(78.13±2.44)	(71.53±2.76)	(69.77±2.29)

[a] The mean yield dependent on oven temperature was significantly different ($P<0.01$).
[b] Mean of 2 rolls.
[c] Mean of 4 rolls.
[d] Mean of 6 rolls.
[e] Standard deviation.

SENSORY STUDIES

Oven roasting temperature and reheating effects.

A split plot design was used to analyze the sensory data for variances. Turkey rolls evaluated at four laboratories were similar in sensory characteristics after roasting at 105, 135, or 165°C with or without 24-hr chilling and reheating. Juiciness was a sensory characteristic that was altered significantly ($P<0.05$) that would have implications for consumers (Figure 5). The least juicy roasts were those cooked at 165°C and reheated. However, when the roasting end-point temperature was 80°C (Illinois and Kansas), samples of turkey rolls cooked at 165°C and reheated were less juicy, only when compared to turkey rolls that were roasted at 105 and 135°C and not reheated.

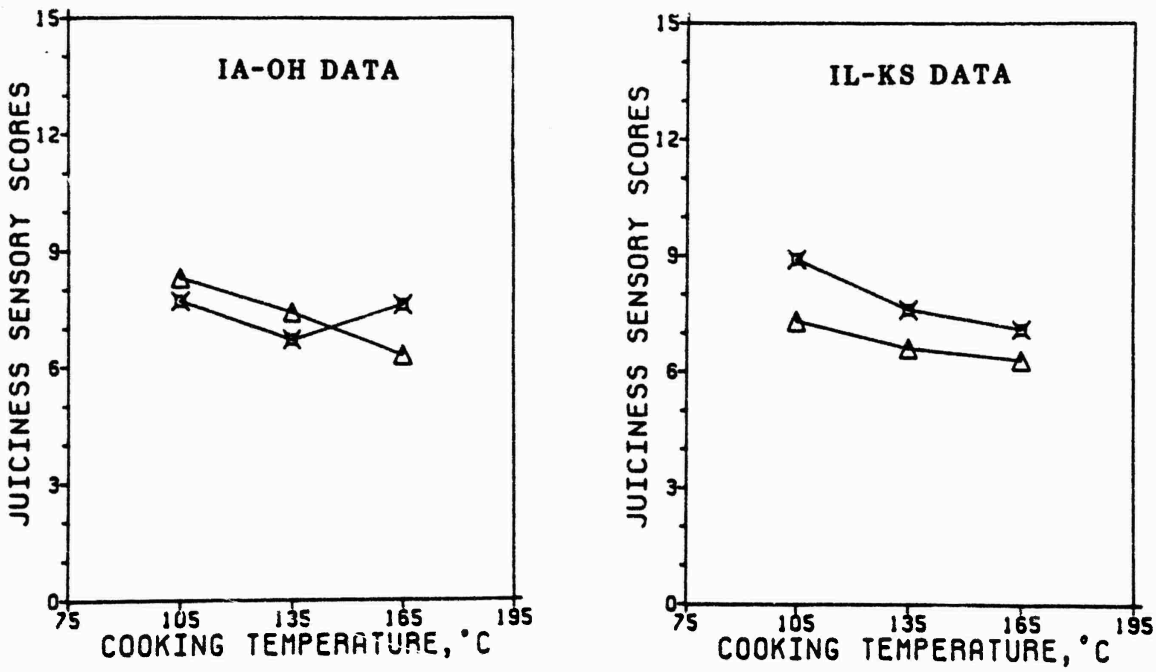

Fig. 5 Mean Scores for Juiciness in Turkey Roasts Cooked at Three Oven Temperatures, with and without Chilling and Reheating.

▲ = chill
Ϫ = no chill

The range of mean scores for chew counts was 12.9 to 22.8 (Table 6). This measurement is based on co   .s of actual chews of standardized samples at a standardized rate, and va. .ations in individuals' mouth structures and dentures would be reflected. This range is considered small for such measurements, making the differences unimportant (11, 12).

For the other characteristics evaluated, some differences were statistically significant (Table 6). However, differences were small (ranges on ballots of 0.8 to 1.4 cm on 15-cm scales) as shown in Figures 6 through 9.

TABLE 6. Least Square Means Showing Treatment Effects on Sensory Parameters of Turkey Roasts.

	Treatments						
	Chill			No Chill			
Attribute[a]	105[b]°C	135°C	165°C	105°C	135°C	165°C	$LSD_{.05}$
AROMA							
IL-KS	9.1^{X}[c]	9.6^{XY}	10.2^{Y}	9.3^{X}	9.3^{X}	9.1^{X}	0.84
IA-OH	9.6^{XY}	9.8^{X}	9.6^{XY}	9.2^{Y}	9.4^{XY}	9.4^{XY}	0.54
FLAVOR							
IL-KS	8.7	8.5	9.4	8.8	8.7	8.9	NS(1.31)
IA-OH	8.6^{Y}	9.2^{X}	8.7^{Y}	8.5^{Y}	8.5^{Y}	8.4^{Y}	0.43
OFF-NOTES							
IL-KS	2.14	1.53	1.74	1.53	1.86	1.91	NS(0.97)
IA-OH	1.76^{Y}	1.94^{XY}	1.73^{Y}	1.79^{Y}	2.35^{X}	2.25^{XY}	0.55
JUICINESS							
IL-KS	7.3^{XY}	6.6^{XY}	6.3^{X}	8.9^{Z}	7.6^{YZ}	7.1^{XY}	1.26
IA-OH	8.3^{X}	7.4^{XY}	6.3^{Z}	7.7^{XY}	6.7^{YZ}	7.6^{XY}	1.02
TEXTURE							
IL-KS	8.5^{X}	7.8^{XY}	7.7^{XY}	7.6^{Y}	7.1^{Y}	7.3^{Y}	0.84
IA-OH	8.4^{X}	8.3^{X}	8.1^{XY}	7.9^{XY}	7.6^{Y}	7.7^{Y}	0.60
CHEW COUNT							
IL-KS	20.8^{XY}	20.2^{X}	22.8^{Z}	21.3^{XYZ}	21.9^{YZ}	21.4^{XYZ}	1.57
IA-OH	12.9	13.6^{XYZ}	13.8^{YZ}	13.3^{XY}	14.1^{Z}	13.9^{YZ}	0.82

NOTE: N = 6 for Illinois and N = 4 for Kansas data (IL-KS) using 80°C end point cooking temperature; N = 7 for Iowa, Ohio data (IA-OH) using 77°C end point cooking temperature.

[a] All scores based on 15-cm intensity scale (0, none; 15, high) except chew count based on actual number of chews at standardized rate.

[b] Cooking temperature.

[c] Means with common letters in same row are not significantly different ($p<0.05$).

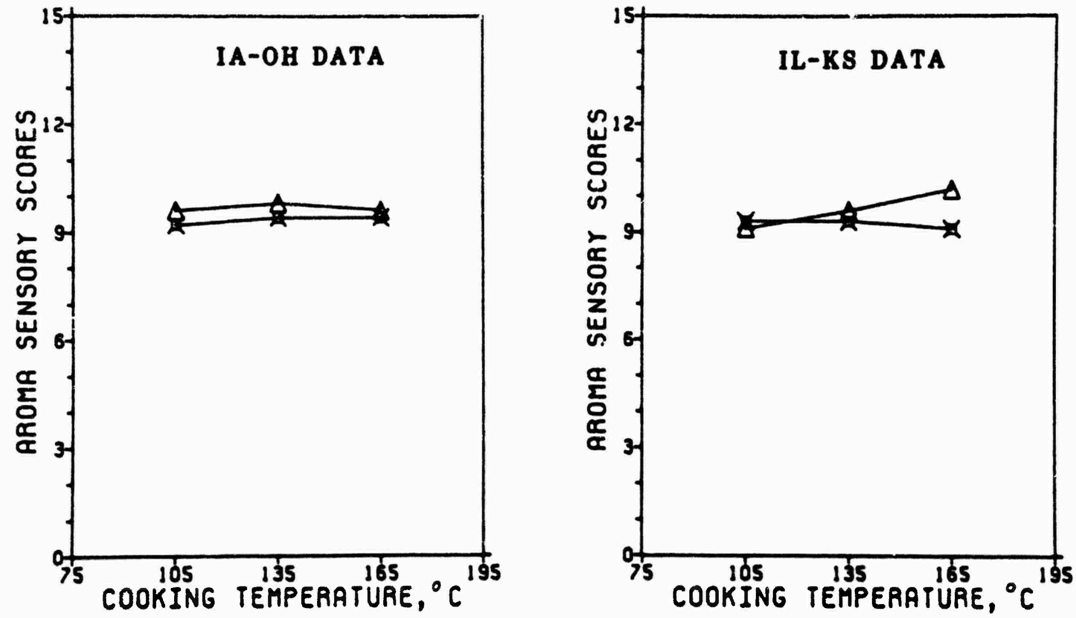

Fig. 6 Mean Scores for Roasted Aroma in Turkey Roasts Cooked at Three Oven Temperatures, with and without Chilling and Reheating.

▲ = chill
⌘ = no chill

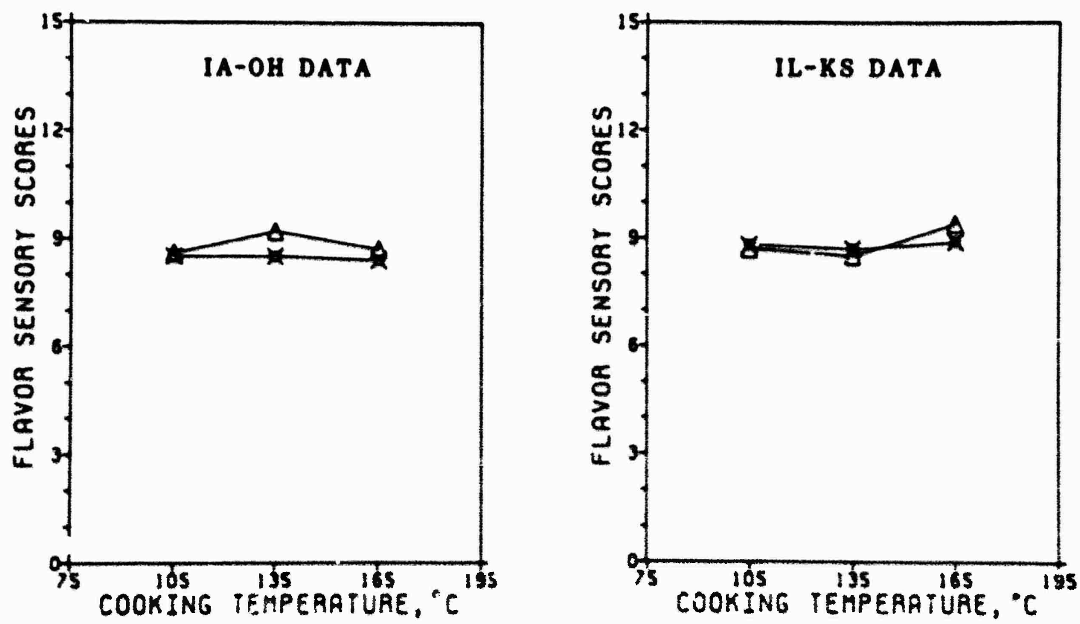

Fig. 7 Mean Scores for Meaty, Cooked Flavor in Turkey Roasts Cooked at Three Oven Temperatures, with and without Chilling and Reheating.

▲ = chill
⌘ = no chill

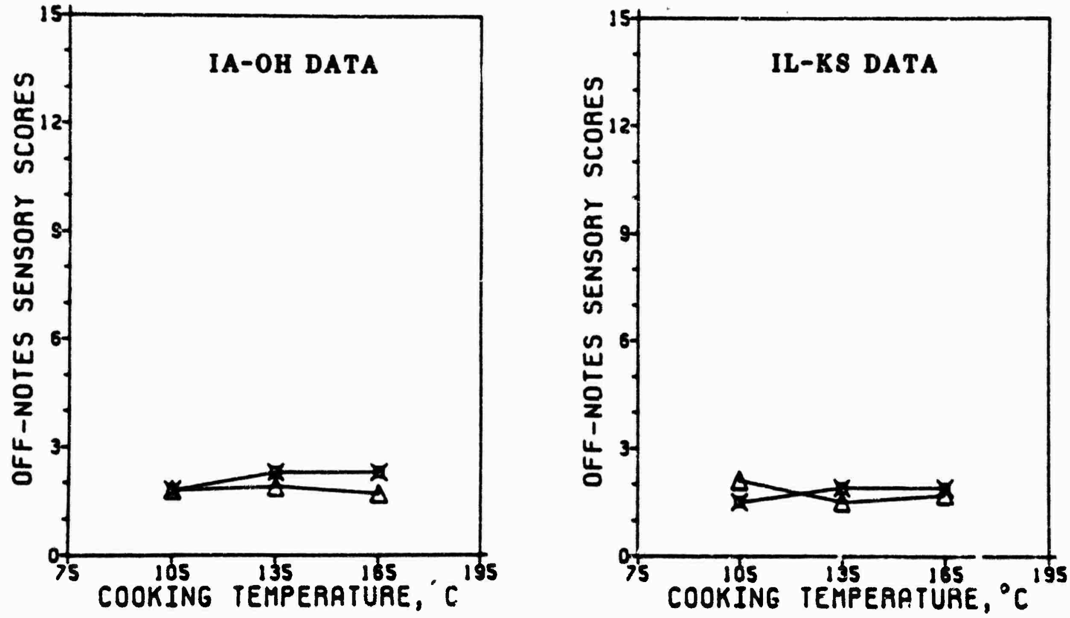

Fig. 8 Mean Scores for Off-Notes in Turkey Roasts Cooked at Three Oven Temperatures, with and without Chilling and Reheating.

▲ = chill
ᴥ = no chill

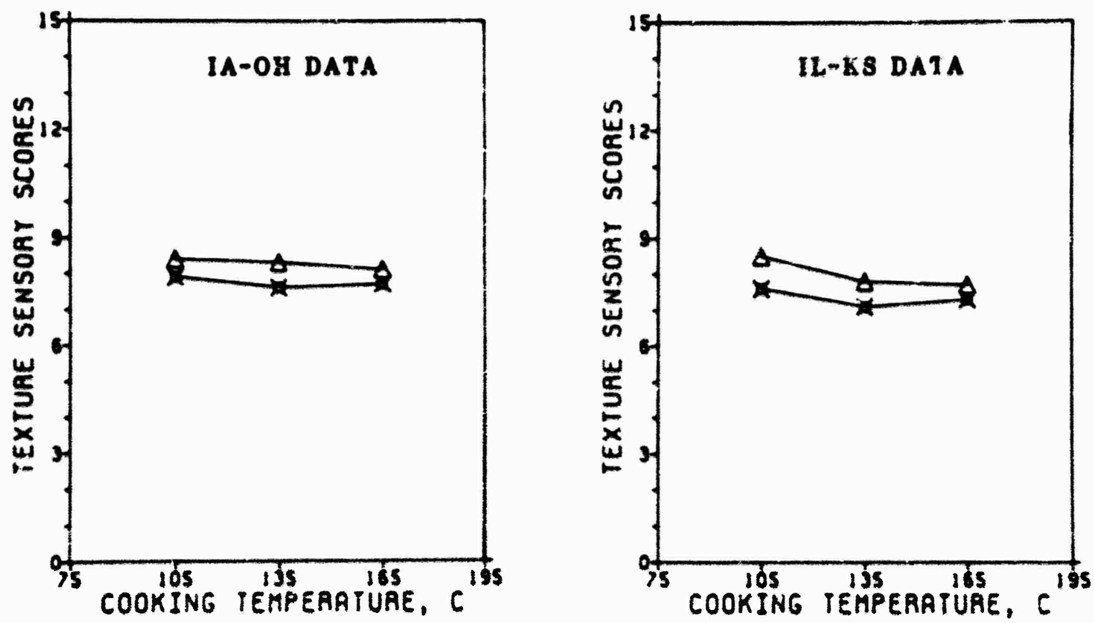

Fig. 9 Mean Scores for Texture in Turkey Roasts Cooked at Three Oven Temperatures, with and without Chilling and Reheating.

▲ = chill
ᴥ = no chill

Holding time effects

Juiciness decreased significantly ($P < 0.05$) as hot-holding progressed. The difference was significant between 0 and 60 min, and roasts cooked to 77°C (Iowa and Ohio) also became progressively less juicy ($P < 0.05$) between 60 and 120 min (Figure 10). Other sensory scores were within such a small range of the total scale that, although some differences were statistically significant (Table 7), these would not likely be discernible by the general population on a first trial basis (Figures 11 and 12). This is because trained panelists are expected to be more discerning than the general population, and generalizing to the consumer on the basis of small differences detected by trained panelists could be risky (13). Sensory scientists are required to use

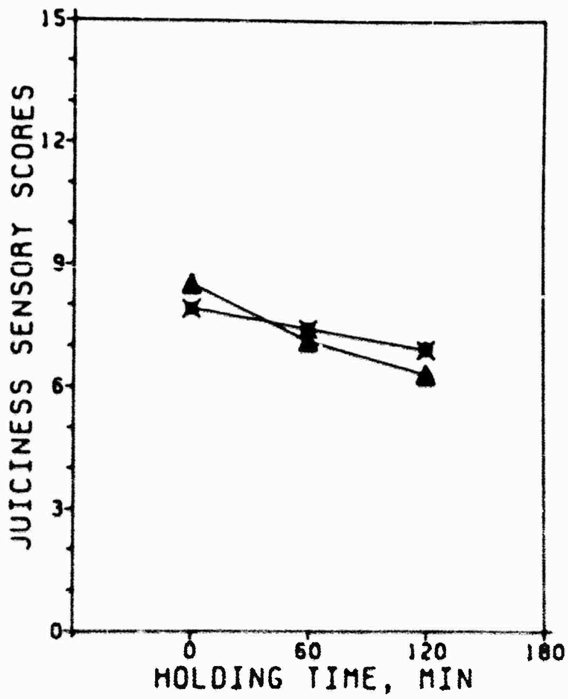

Fig. 10 Mean Scores Pooled for All Treatment Combinations for Juiciness of Turkey Roasts After Hot-Holding 0, 60 and 120 min at 105°C.

▲ = IL - KN
✕ = IA - OH

TABLE 7. Least Square Means Showing Holding Time Effects on Sensory Parameters of Turkey Roasts.

Attribute[a]	Holding Time (Min) 0	60	120	LSD .05
AROMA				
IL-KS	9.3^{X}[b]	9.2^{X}	9.8^{Y}	0.45
IA-OH	9.0^{X}	9.6^{Y}	10.0^{Z}	0.36
FLAVOR				
IL-KS	8.9	8.9	8.6	NS(0.58)
IA-OH	8.5	8.6	8.9	NS(0.39)
OFF-NOTES				
IL-KS	1.5^{X}	1.8^{XY}	2.0^{Y}	0.44
IA-OH	1.9	2.0	2.1	NS(0.33)
JUICINESS				
IL-KS	8.5^{X}	7.1^{Y}	6.3^{Y}	0.90
IA-OH	7.9^{X}	7.4^{Y}	6.9^{Z}	0.45
TEXTURE				
IL-KS	7.3	7.9	7.6	NS(0.69)
IA-OH	7.8^{X}	8.0^{XY}	8.2^{Y}	0.32
CHEW COUNT				
IL-KS	20.4^{X}	21.2^{X}	22.6^{Y}	0.98
IA-OH	14.0^{X}	13.3^{Y}	13.4^{XY}	0.61

NOTE: N=6 for Illinois and N = 4 for Kansas data (IL-KS); N=7 for Iowa, Ohio (IA-OH) data.

[a] All scores based on 15-cm intensity scale (0, none; 15, high) except chew count based on actual number of chews at standardized rate.

[b] Means with common letters in same row are not significantly different ($p < 0.05$).

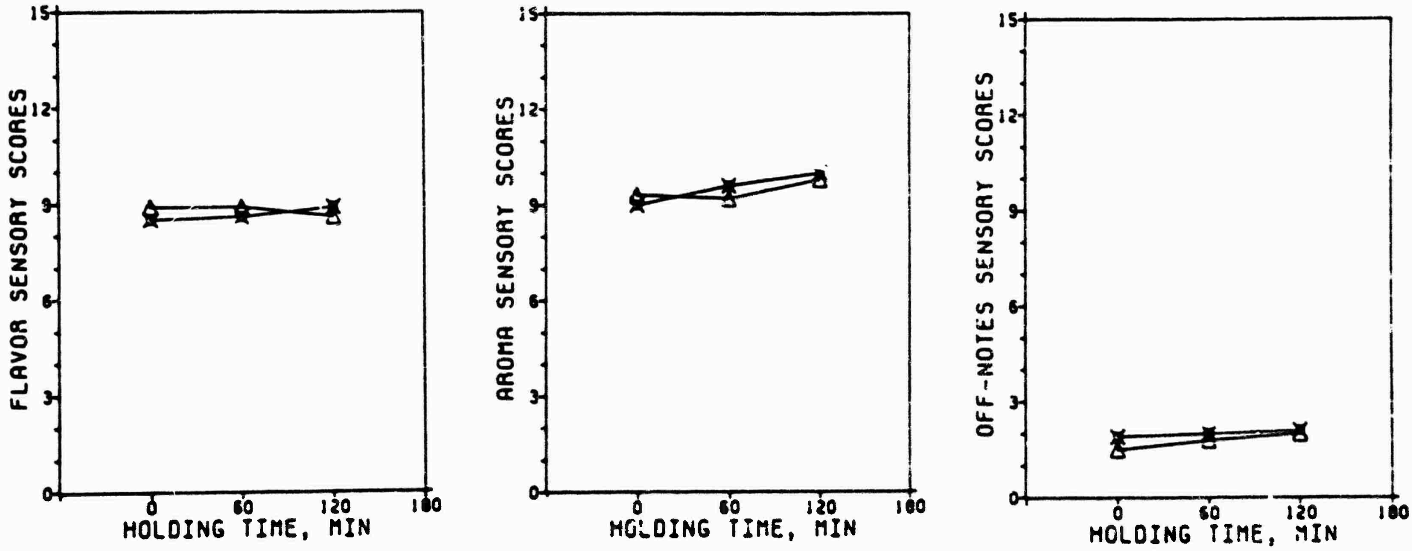

Fig. 11 Mean Scores Pooled for All Treatment Combinations for Sensory Flavor Attributes of Turkey Roasts After Hot-Holding 0, 60, and 120 min at 105°C.

▲ = IL - KN
X = IA - OH

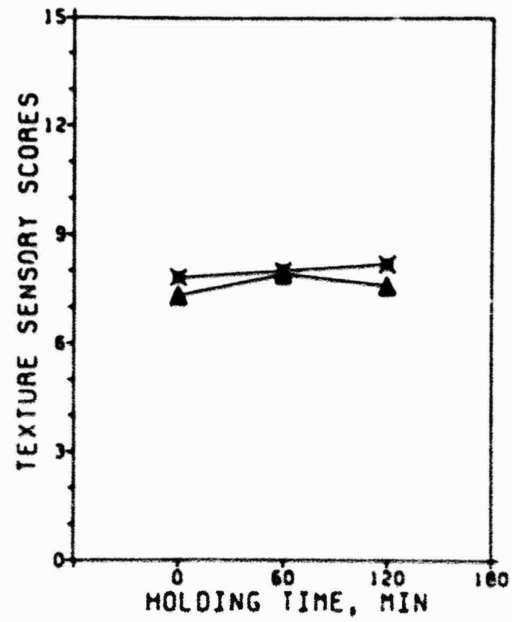

Fig. 12 Mean Scores Pooled for All Treatment Combinations for Crumbly, Mealy Texture of Turkey Roasts After Hot-Holding 0, 60, and 120 min at 105°C.

▲ = IL - KN
X = IA - OH

a pragmatic approach, generally utilizing parametric statistical methods (ANOVA) even though the scaling data might not be distributed normally. Thus, a sensory scientist should consider the analysis only a "rough and ready" approach (14). Under those circumstances, one could go amiss placing great emphasis upon sensory scores with small variances even though the differences are statistically significant.

Other Observations

One of the interesting aspects of this study, from a sensory methodological perspective, involved a comparison of data using panels selected by two procedures. The researchers at each location trained taste panelists equally at that location. Iowa and Ohio each selected panelists, trained them, and used the same panelists for each evaluation period throughout the study. On the other hand, Illinois and Kansas each trained 12 panelists to serve as a pool of trained panelists, and for each evaluation period selected a smaller, constant number of panelists at random to serve as the evaluators.

Comparisons of the variances for the panels using Hartley's F-max test for homogeneity of variances (15), normalized to account for differences in panel size at each of the four Agricultural Experiment Stations, did not indicate differences related to training one group and selecting a portion of the group for the individual sessions versus selecting one constant group and training and using the entire group each session (Table 8). Differences ($p<0.05$) in variances among groups for flavor could be related to use of wider sections of the scale to assess the attributes by some groups (Table 8). Another possibility is use of different portions of the scale by different groups.

TABLE 8. Experimental Error Variances of Sensory Data.

Station	Roasted Aroma	Juiciness	Mealy or Fibrous Texture	Chew Count	Flavor	Off-notes	Panel Size
ILLINOIS	8.05	15.69	6.63	32.52	9.11	17.16	6
KANSAS	6.21	15.72	7.16	19.11	22.36	4.25	4
IOWA	4.58	13.82	6.36	10.68	2.15	4.79	6
OHIO	3.80	17.70	4.02	8.88	3.51	4.25	9
F_{max} =	2.12	1.28	1.73	1.79	10.41*	4.04	

*The 5% critical point for the F_{max} test for four Agricultural Experiment Stations with df = 10 is 5.67. Thus flavor was the only sensory attribute for which a significant difference existed among the four Experiment Stations.

Training is essential to develop a common language to describe the characteristics and to improve a panel's ability to make consistent judgments. Each panel can meet these criteria, yet the degree to which one group interprets how intensely the standard is found in a product can easily differ with another group of panelists. One of the difficulties in combining data using different panels will always be this very matter. Consistency of performance might be improved by tight definition and control of reference standards for each attribute. Some differences in interpreting references and arriving at a consensus regarding their usage (16) are inherent in any study using human instruments, even though mean scores were used for the actual data analyses.

NUTRITIONAL STUDIES

Thiamin content of raw white turkey muscle analyzed at Illinois was 77 mcg/100g. This is comparable to previously reported values (17, 18). Raw turkey meat at the other Agricultural Experiment Stations was not analyzed.

Thiamin content of the cooked white meat was analyzed at Kansas, Illinois, Wisconsin, and Iowa. Results are shown in Table 9 and Figure 13 (Illinois only). Heat treatment, e.g. oven temperature, as well as chilling cooked roasts, significantly ($P<0.001$) affected the thiamin content of turkey meat on the wet-weight basis. As can be seen in Table 9, the values for Illinois are

TABLE 9. Thiamin Content[a] (mcg/100g) of Cooked White Turkey Meat.

Cooking Temperature (°C) and Chill State	Holding Time (min)	Kansas	Illinois	Wisconsin	Iowa
105 NC	0	53.3	53.7	57.7	35.2
	60	58.8	53.0	60.3	34.5
	120	58.8	52.3	62.3	35.3
105 C	0	37.7	65.0	ND[b]	33.4
	60	43.0	62.7	ND	32.1
	120	40.3	60.3	ND	33.9
135 NC	0	40.7	51.7	43.0	34.4
	60	44.3	50.3	51.7	33.7
	120	42.7	50.0	39.0	35.0
135 C	0	39.0	55.7	ND	34.4
	60	42.0	56.0	ND	34.4
	120	35.0	52.3	ND	34.7
165 NC	0	38.0	49.0	45.3	33.8
	60	30.0	47.7	55.7	31.8
	120	35.7	47.0	36.3	31.4
165 C	0	46.3	50.0	ND	34.0
	60	42.3	47.3	ND	29.5
	120	37.0	45.0	ND	30.5

Note: Chill state (Nonchill = NC, Chill = C) prior to hot-holding.
[a]On wet-weight basis.
[b]ND = Not Determined.

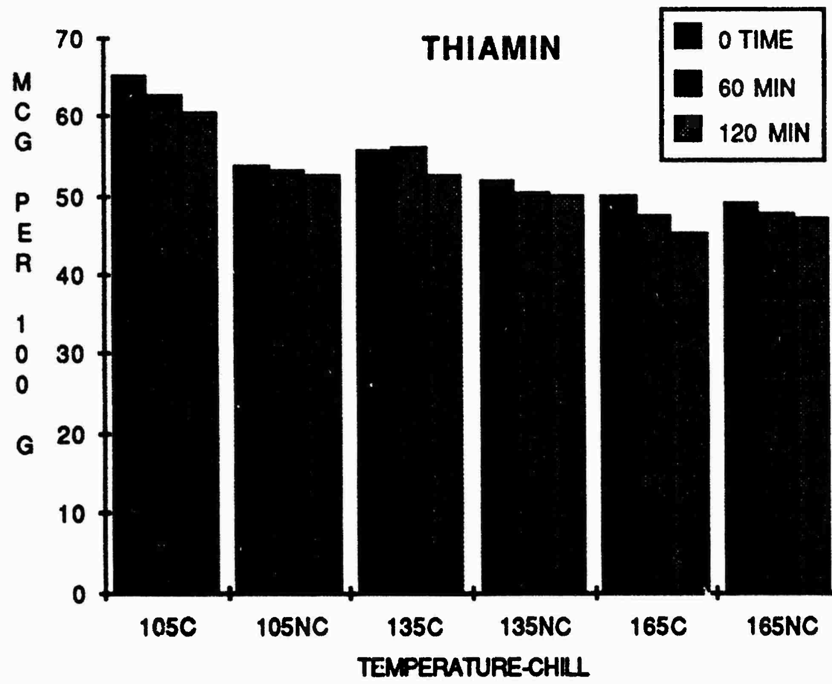

Figure 13. Thiamin Content of White Turkey Meat at Illinois. Note: Chill state (Nonchill = NC, Chill for 24 hr. = C) prior to hot-holding. Thiamin content was on the wet-weight basis.

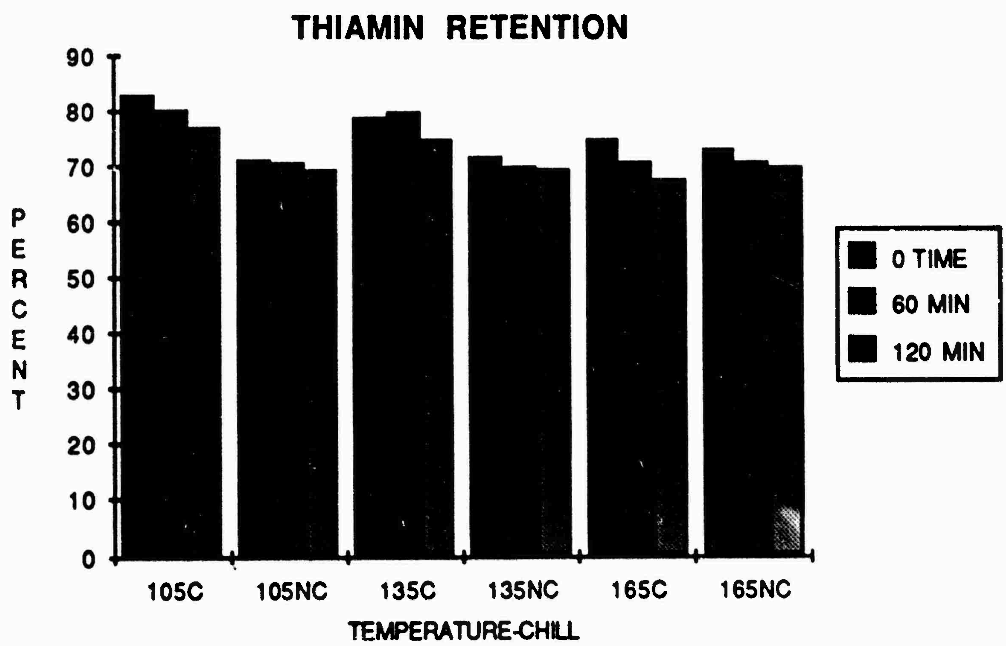

Figure 14. Percentage Thiamin Retention in White Turkey Meat at Illinois. Note: Chill state (nonchill = NC, chill for 24 hr = C) prior to hot-holding.

generally higher than for the other three states, although on the moisture and fat-free basis, values are comparable. Thiamin content in cooked turkey decreased significantly ($P<0.05$) with increasing temperature; percentage thiamin retention followed a similar trend (Figure 14, Illinois only). The effect of chilling prior to reheating and holding versus hot-holding directly after cooking was significant ($P<0.001$). In the Illinois study, thiamin content and retention in the chilled meat was higher than in the nonchilled meat. Neither the data from Iowa nor Kansas showed a difference in thiamin retention due to chilling of the meat.

Holding time following cooking or reheating significantly influenced thiamin content. In the Illinois study, there was a consistent effect of holding time: a decrease in thiamin content was observed as holding time increased.

Wisconsin and Iowa used institutional methods of preparation for the turkey rolls. No significant differences were found between heat treatments, holding time, or chill state (done at Iowa only). Overall, thiamin values were lowest in the Iowa study. This finding may be attributed to the fact that the roasts were covered during cooking. Thus thiamin, which is water soluble, could have been lost in the drippings. Moisture content of cooked roasts ranged between 66.7 and 70.3%. Fat content in turkey roasts at Illinois averaged 1.86%, and at Kansas 5.02%.

Statistical analysis was completed on combined values for Illinois and Kansas, because the same preparation procedures and analytical methods were used. Comparison of thiamin values obtained for a check sample (Gerber strained pork) agreed closely. The coefficient of variation for thiamin values for the two states was 7.80, which indicated good reproducibility of the data between and within laboratories. Differences observed in thiamin content in turkey roasts analyzed in the two Agricultural Experiment Stations could be attributed to variability in raw material. When thiamin values obtained at Kansas and Illinois were adjusted for moisture and fat content of the turkey meat and expressed on the moisture and fat-free basis, differences (134-209 mcg/100g) were not statistically significant.

Implications

The practices of pre-cooking meats and holding, either hot or chilled, are common in the foodservice industry. Nutrient content, as measured by losses of the indicator vitamin thiamin, decreased during the holding period. Earlier studies reported that the destruction of thiamin ranged between 25 and 40% during cooking of turkey or chicken, depending on end-point temperature and cooking temperature (19-21).

The NC-120 study was designed to determine if convection heating of turkey rolls by either home or foodservice techniques resulted in similar values for thiamin retention. Results showed that differences were small and not of practical importance. Chilling meat and then reheating did not have a detrimental effect on thiamin retention. Differences in procedures (e.g. covered vs. uncovered pans, oven loads) between home and foodservice operations could account, in part, for variability in the values observed.

Low temperature cooking (105°C) is another foodservice practice that is believed to result in higher yield and better sensory and, perhaps, nutritional characteristics. In this collaborative study, thiamin content and retention were similar in all cooking and holding procedures. Thus it appears that using recommended times, temperatures, and procedures for microbiologically safe and sensorially acceptable turkey roasts results in satisfactory nutritional quality.

MICROBIOLOGICAL SAFETY

Raw Product

Total aerobic plate counts on surfaces of turkey rolls ranged from 10,000 to 560,000/g as shown in log format in Tables 10 and 11. There was good agreement in results from the three Agriculture Experiment Stations (Minnesota, Nebraska, and Wisconsin) although there were minor differences in methodology. Observations were made by Minnesota and Nebraska on the internal section of the rolls. The magnitude and range of internal counts were similar to those observed for the surface counts (Table 10), thereby indicating the same extent of contamination throughout the rolls. This microbial load was below that commonly accepted by state regulatory agencies (22).

Coliform counts on surface samples were highly variable and ranged from below the level of detection to 4,800/g as shown in Tables 10 and 11. The inner portion of the rolls contained similar numbers of coliform contamination as those observed on the surfaces (Table 10).

Cooked Product

Roasting the turkey rolls at 135°C (Minnesota and Nebraska) to an internal temperature of 77 to 82°C reduced the total aerobic plate count to 300/g or less. These results were in harmony with previous observations using a similar quantity of meatloaf (23). No coliform organisms were detected in cooked turkey at Minnesota and Nebraska. The lowest total aerobic count in roasted turkey after hot-holding (Wisconsin) was below the detectable level by commonly used methods and the highest count was approximately 300/g (Table 12). Thus, it was apparent that a major portion of the contaminating microflora was extremely heat sensitive. Although total aerobic plate count increased in these trials during hot-holding, this increase could be attributed to sampling error, recontamination, or laboratory error.

TABLE 10. Microbial Evaluation of Surface and Core Samples of Raw Turkey Rolls at Minnesota and Nebraska.

	Log of Total Aerobic Plate Count			
	Surface Samples		Core Samples	
Trial	Minnesota	Nebraska	Minnesota	Nebraska
1	4.48	4.00	4.34	3.78
2	4.66	4.98	5.38	3.60
3	4.97	4.61	5.04	4.69
4	5.48	4.81	5.91	4.48
Average	4.90	4.36	5.17	4.14
	Log of Coliform Count			
	Surface Samples		Core Samples	
Trial	Minnesota	Nebraska	Minnesota	Nebraska
1	2.20	<1	1.90	<1
2	3.04	<1	2.60	<1
3	2.70	<1	1.85	<1
4	3.34	<1	2.76	<1
Average*	2.82	<1	2.28	<1

*Average values used <1 as 1

TABLE 11. Microbial Evaluation of Surface Samples of Raw Turkey Rolls at Wisconsin.

Trial	Log Total Count	Log Coliform Count
1	4.72	<1
2	5.28	3.45
3	5.40	3.06
4	4.71	2.26
5	5.70	2.46
6	5.75	3.68
7	4.73	3.33
8	5.11	<1
9	5.26	3.23
10	5.41	NA[a]
Average[b]	5.21	2.61

[a]NA = not available.
[b]Average values used <1 as 1.

TABLE 12. The Effect of Cooking to 77°C and Subsequent Hot-Holding on the Total Microflora of Turkey Roasts at Wisconsin.

Oven Temperature	Log Total Count				
			Holding time in minutes		
°C	Raw	Cooked to 77°C	0	60	120
165	4.72	3.51	1.85	<1	<1
105	5.28	<1	2.48	1.95	<1
135	5.40	1.00	1.00	1.70	1.00
105	4.71	1.18	2.20	<1	1.93
135	5.70	3.23	1.70	<1	1.30
135	5.75	1.74	1.18	1.90	1.30
165	4.73	<1	<1	<1	<1
165	5.11	4.40	2.11	NA[a]	<1
105	5.26	2.45	0.70	<1	<1
105	5.41	0.70	1.48	<1	1.30
Average[b]	5.21	2.02	1.57	1.28	1.18

[a]NA=not available.
[b]Average values used <1 as 1.

Complete elimination of the coliforms was attained by roasting to a temperature as low as 77°C at the geometric center of a turkey roast. These data support the observation of extreme heat sensitivity of the contaminating microflora.

CHEMICAL SAFETY

Results of the polychlorinated biphenyl (PCB) analyses for turkey rolls obtained from four Agricultural Experiment Stations that had received product from the common lot of turkey rolls supplied by this contract, established that these turkey rolls had nondetectable levels of PCBs. Figure 3 compares the GLC/integrator curve of one of the turkey roll samples analyzed from product obtained from Kansas with that of an Aroclor 1254 standard.

Although PCB spill accidents have resulted in feed contamination and subsequent poultry contamination in localized areas, the general levels of PCBs in meat, fish, and poultry have declined. Thus, although it is not surprising, it is reassuring to find nondetectable levels of PCBs in these turkey rolls.

The U.S. Food and Drug Administration (FDA) conducts Total Dietary Studies to determine the dietary intake of pesticides, industrial chemicals, heavy metal, and radionuclides. These studies involve retail purchases throughout the year of 12 food groups for adult diets from selected cities in five districts. The latest published data gave the results of analyses in 1980-82 (24). Two of the meat, fish and poultry groups had detectable levels of PCBs with the range in concentration of these positive samples reported as being a trace. For both 1978-79 and 1979-80, two of the 20 meat composites were positive and the average level reported was a trace (25-26). For the 1977-78 sample data, five composites of meat, fish and poultry from the 20 cities monitored showed positive PCB results (27). One of the composites had 0.05 ppm, while four had trace levels. Thus, the general levels of PCB residue in meat, fish, and poultry in representative retail markets have declined to trace or nondetectable levels.

ENERGY USE

Analysis of variance procedures for the data given in Table 13, when two turkey rolls were heat processed, revealed that increasing the oven temperature did not significantly increase the total processing losses. Product yields for the turkey roasts ranged from 76 to 82%.

TABLE 13. Heat Processing Parameters and Energy Consumption for Turkey Roasts at Iowa and Missouri.[a]

	Oven Temperature (°C)					
	105		135		165	
Variables	Mean	S.E.	Mean	S.E.	Mean	S.E.
Initial mass (g)	9932^{X}[b]	39	10028^{Y}	17	9973^{XY}	19
Final mass (g)	8167	266	7748	227	7565	256
Total processing loss (%)	17.79	2.47	22.75	2.16	24.13	2.61
Yield (%)	82.21	2.47	77.25	2.16	75.86	2.61
Heat processing time:						
(min/load)	263^{X}	5.5	189^{Y}	5.8	163^{Z}	1.9
(min/kg)	26.42^{X}	0.45	18.86^{Y}	0.55	16.32^{Z}	0.19
Energy usage:						
(Wh/load)	5406^{X}	397	6077^{XY}	271	6509^{Y}	296
(Wh/kg)	545^{X}	41	606^{XY}	28	653^{Y}	29

[a]Two turkey rolls were heat processed, uncovered in separate pans, at one time. Roasts were removed from the oven when both internal temperatures had reached 77°C.
N = 6; except for 165°C where N = 5.

[b]Means followed by the same letter within a row were not significantly different ($P<0.05$).

Because of the various weights of the raw turkey rolls, the mean initial weight for the turkey rolls processed at 105°C was lower than for those processed at 135°C. When the heat processing times were expressed on both a load (min/load) and weight (min/kg) basis, significant differences ($P<0.05$) were found among the three oven temperatures. The highest oven temperature required less time than the two lower temperatures.

Energy consumption did not follow this trend. On both an energy usage per load (Wh/load) and weight (Wh/kg) basis, the highest oven temperature required more energy than the lowest one. However, no significant differences were revealed between oven temperatures of 105 and 135°C, and between 135 and 165°C.

Thus, when only two turkey ro' are required, foodservice administrators have the assurance that food product yield will not be significantly lowered by choosing any of these three conditions with the Lange Model (ECCO-6) of forced-air convection oven. If 165°C is chosen, processing time is reduced and energy consumption is increased. If 135°C is used, energy consumption is not significantly reduced, but processing time is significantly reduced. Choosing the last option (105°C) significantly ($P<0.05$) increases the required heat processing time, but does not significantly reduce energy consumption, compared to the 135°C temperature. Clearly, variables other than heat processing time and energy usage should be included in the decision making process.

An analysis of variance revealed significant differences among the heat processing parameters for turkey rolls (Table 4). Data in Table 14 include findings when three different oven loads of turkey rolls were heat processed at an oven temperature of 135°C. Energy usage (Table 14) was significantly greater on an oven load basis when 6 rolls were heat processed simultaneously, versus either 2 or 4 rolls. When energy usage was analyzed on a weight basis

TABLE 14. Energy Usage for Heat Processing Three Oven Load Sizes of Turkey Roasts.

Oven Temp		Load Size	Heat Processing (min/load)		Heat Processing (min/kg)		Energy Usage (Wh/load)		Energy Usage (Wh/kg)	
(°C)	N[a]	Rolls	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
135	3	2	178[Y,b]	6.9	17.82[X]	0.66	6666[Z]	140.2	666[X]	13.0
135	3	4	214[X]	6.6	10.70[Y]	0.33	7658[Y]	151.7	383[Y]	7.7
135	3	6	233[X]	3.6	7.64[Z]	0.10	11144[X]	137.6	365[Y]	2.9

NOTE: Combined data from Iowa and Missouri.

[a]Refers to the number of replications.

[b]Means followed by the same letter within a column were not significantly different ($P<0.05$).

(watthours per kilogram of raw turkey roll), significantly ($P<0.05$) greater amounts of energy were consumed for the oven load with 2 rolls.

Information in Table 14 represents an interesting finding for the foodservice manager. When either 4 or 6 turkey rolls were heat processed, no significant difference in heat processing times for an oven load was revealed. Furthermore, no significant difference in energy consumption per kilogram of raw turkey rolls was revealed at these oven loads. Therefore, when 6 turkey rolls are required, energy i conserved by heat processing them together, instead of having one oven load with 2 rolls and another with 4 rolls. Information shown in Table 14 revealed that the latter option required 14.3 kilowatt hours of energy, or 22% more energy than if all 6 rolls were processed together in one oven.

Energy data from Wisconsin are given in Table 15 for each of the nine treatments studied. When compared to energy data for the ovens used at Iowa and Missouri, these data were considerably higher. The kilowatt rating for the Lang convection oven is 10.8 kW; for the Blodgett (used at Wisconsin), 11.0 kW. Direct comparisons between the two models of forced-air convection ovens can not be made because both models have different efficiencies. For example, at 105°C with two turkey rolls, the Lang model operated at 11% of the heat processing time; the Blodgett, 24% (Tables 13 and 15). The latter model is an older one with different insulation and thermostat controls and had greater heat losses via the cavity walls, doors and vents.

Several trends are apparent from the data given in Table 15. As the load size increased for each of the three oven temperatures, the per unit heat processing time (min/kg) and energy usage (Wh/kg) decreased. The heat processing time decreased as the oven temperature increased as expressed on an oven load basis. However, heat processing time for loads of 4 and 6 rolls was similar for the three

TABLE 15. Energy Usage for Heat Processing Turkey Roasts at Wisconsin.

Oven Temp (°C)	Load size (No Rolls)	Heat Processing (min/load)	Heat Processing (min/kg)*	Energy Usage (Wh/load)	Energy Usage (Wh/kg)*
105	2	267	26.86	10713	1078
	4	288	14.29	13430	666
	6	289	9.81	14946	507
135	2	199	20.20	11316	1149
	4	216	11.09	14234	731
	6	211	7.13	16947	572
165	2	162	15.62	11651	1196
	4	186.5	9.49	15100	769
	6	193	6.57	18714	637

NOTE: A three by three factorial design (three oven temperatures x three oven load sizes) was used to monitor energy consumption and time for heat processing in a convection oven. Only one trial was conducted for each treatment; thus, nine trials were conducted. Additionally, one experiment with load size of 2 rolls at oven temperature of 105°C was repeated to assess consistency of the experiments.

* Min/kg and Wh/kg was based on weight of raw turkey meat.

oven temperatures. As anticipated, total energy consumption increased as the size of the oven load increased from two to six turkey rolls.

Information given in Table 15 for the oven temperature of 135°C follows similar trends to the significant ($P<0.05$) findings revealed at Iowa and Missouri (Table 14). In addition, similar trends are revealed when only two turkey rolls were heat processed (Table 13): (a) heat processing time decreased as oven temperature increased, and (b) energy usage (Wh/load) and (Wh/kg) increased as oven temperature increased. If foodservice managers are concerned about energy usage, oven load size of 6 rolls heated at 105°C will save 11% and 20% energy (Wh/kg), compared to rolls heated at 135 and 165°C (Table 15). However, oven load size of 6 rolls heated at 165°C will save 33% and 8% cooking time (min/kg), compared to rolls heated at 105°C and 135°C (Table 15). Although oven load size of 6 rolls heated at 135°C took more time (8%) than those heated at 165°C, the oven load size of 6 rolls heated at 135°C. saved more energy (10%) than those heated at 165°C. Therefore, oven load size of 6 rolls heated at 135°C or 165°C would be recommended if both heating time and energy use are of concern.

Foodservice managers need to recognize that although the largest oven load can save more energy during heat processing, the storage and reheating of leftovers could require additional energy consumption. Energy usage of three hot-holding loads (4, 8, or 12 pans) was not significantly different after one and two hours of hot-holding in the cabinet at Wisconsin. Hence, the size of the loads did not affect the energy consumption during hot-holding. At Iowa, reheating time and the amount of energy to reheat turkey slices to 66°C and to hold at that temperature for up to 2 hr were not significantly different for slices originally cooked at different temperatures.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are supported by the results of this project.

1. Sensory quality can be maintained while minimizing last minute preparation time by using low temperatures and long roasting times for roasting turkey rolls. However, should other procedures (short, high temperature roasting; roasting, chilling, and reheating) fit scheduling, personnel management, equipment availability, and energy saving requirements, sensory quality is not affected as adversely as is believed generally.

2. Nutrient content of turkey rolls, as measured by losses of the indicator-vitamin thiamin, was decreased slightly by heat processing. However, the losses of the labile vitamin were small and probably not of practical importance. Using recommended times, temperatures and procedures for preparing acceptable turkey roasts results in satisfactory nutritional quality.

3. The variable counts of both total and coliform organisms constitute potential for spoilage if turkey rolls are mishandled in the either raw or cooked state. Roasting to an internal temperature of 77°C destroyed coliforms and reduced the total aerobic count, however, some residual organisms of no public hazard remained.

4. This lot of commercial turkey rolls did not contain detectable levels of PCBs. Continued surveillance of the U.S. food supply, however, is necessary to ensure that environmental translocations and/or accidental spills do not cause food contamination with these types of industrial chemicals.

5. Based upon the experiments with two models of convection ovens, when two turkey rolls are required, an oven temperature of 135°C would be recommended. This option consumed less energy on a watthour per kilogram of product weight basis. When either four or six rolls are required, oven temperatures of either 135°C or 165°C consume similar levels of energy, when analyzed on a product weight basis.

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